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Demonstration of fast wide angle scatterometry for CD metrology using laboratory DPP-XUV source.

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Introduction

Non-destructive, high precision, high throughput characterization methods of critical dimensions and pattern cross sections are critical to the maturation of sub-30 nm technologies. New demands are arising with sub 20 nm half pitch structured wafers and with reflective EUV masks.

Having the drawback of existing and candidate approaches in mind, we suggest that the availability of EUV and XUV technology may provide a path to overcome most of the issues. In a first proof of concept experiment, we realized CD measurements on 50 nm half pith structures on < 0.1 mm² footprint with a laboratory discharge source with 5 seconds exposure time. With DPP source flexibility, wavelengths can be matched to best process sensitivity and efficiency; e.g. to inband EUV at 13.5 nm for actinic CD measurements on EUV masks. Tool development roadmap and ultimate limits are discussed.

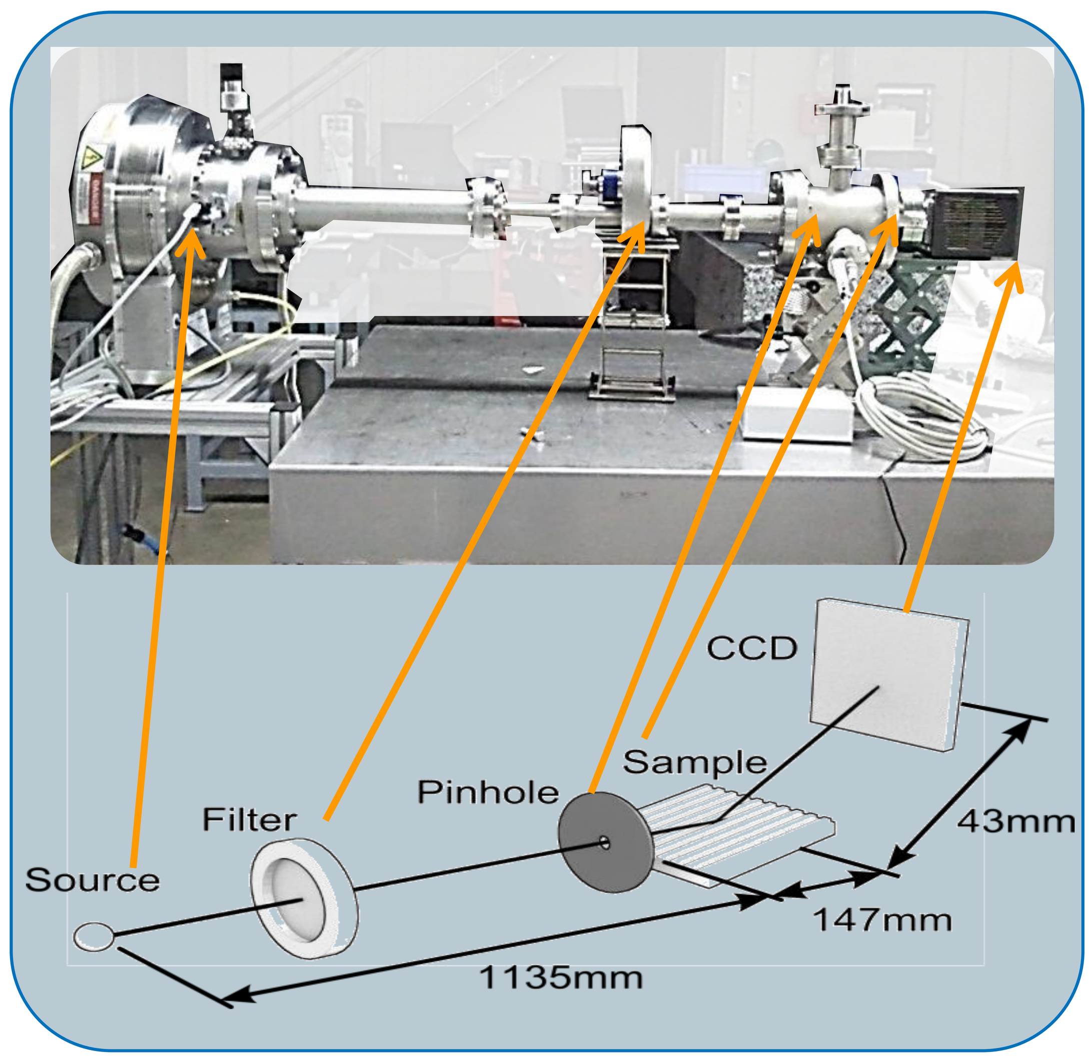
Status of other techniques

Technique	Feature
CD-SEM	+ has very high resolution - on any isolated features, only - low statistics -low throughput - pattern degradation in resist films
optical CD (OCD) or scatterometry	+ established, known + reasonable fast; + minimum damage - Large Footprint. on sample With sub 30 nm features: - Limited resolution - Complex models may be needed. - Significantly longer acquisition
Small Angle X-ray Scattering (CD-SAXS)	+ is a n industrial candidate + sub-nm precision. Traditional in reflection: - large footprints (small grazing angles) or in transmission : -low throughput in transmission
WA-XUV-S	-Only feasibility, yet + larger angles than CD-R-SAXS + Small footprint possible + Sub-minute exposure

Why XUV for CD metrology ?

- XUV and EUV Technology and **components (sources, optics) are readily available**
  - From Developments for EUV-Lithography Metrology
  - From Developments for X-Ray Microscopy
- XUV and EUV **offer**
  - High Interaction with Nanostructures ➔ Efficiency
  - Higher Angle of Incidence for Grazing Incidence Reflectometry (> 5°) ➔ Geometry, Efficiency
  - Wavelengths in the range of 1 – 20 nm allow for matching to future CDs on masks and wafers. ➔ Flexibility
  - Actinic CD measurements on EUV-Masks
- Calibrated, narrowband plasma emission wavelengths ($\lambda/\Delta\lambda$>10.000) with Lab sources
  - allow for reference-free high accuracy
  - High brightness in the range of > 1 W/ mm²/sr is available
- Experience on XUV and EUV tools at Bruker ASC GmbH
  - XUV Lab Sources at BASC (AIXUV) since 1999.
  - Integrated Tool Solutions developed in the past like Reflectometer, Spectrophotometers and Exposers
  - Platforms for vacuum solutions in EUV-Mask blank (EUV-MBR) and wafer handling (AXS: TXRF) available

Proof of Feasibility Experiment



Straight forward compact Proof of feasibility experiment set-up with available lab components at BASC.

Proof of feasibility experiment has been realized with available lab components at BASC:

- Available standard EUV Lamp
  - Gas discharge source
  - < 0.5 mm FWHM diameter source diameter (EUV
  - 5 -200 Hz Reprate
  - Optimized for Xe EUV emission
  - Operated with various plasma gases
  - 1 – 60 seconds exposure

Spectral Purity Filter

Collimating Pinhole

➔ small footprint

➔ collimated to 350 µrad

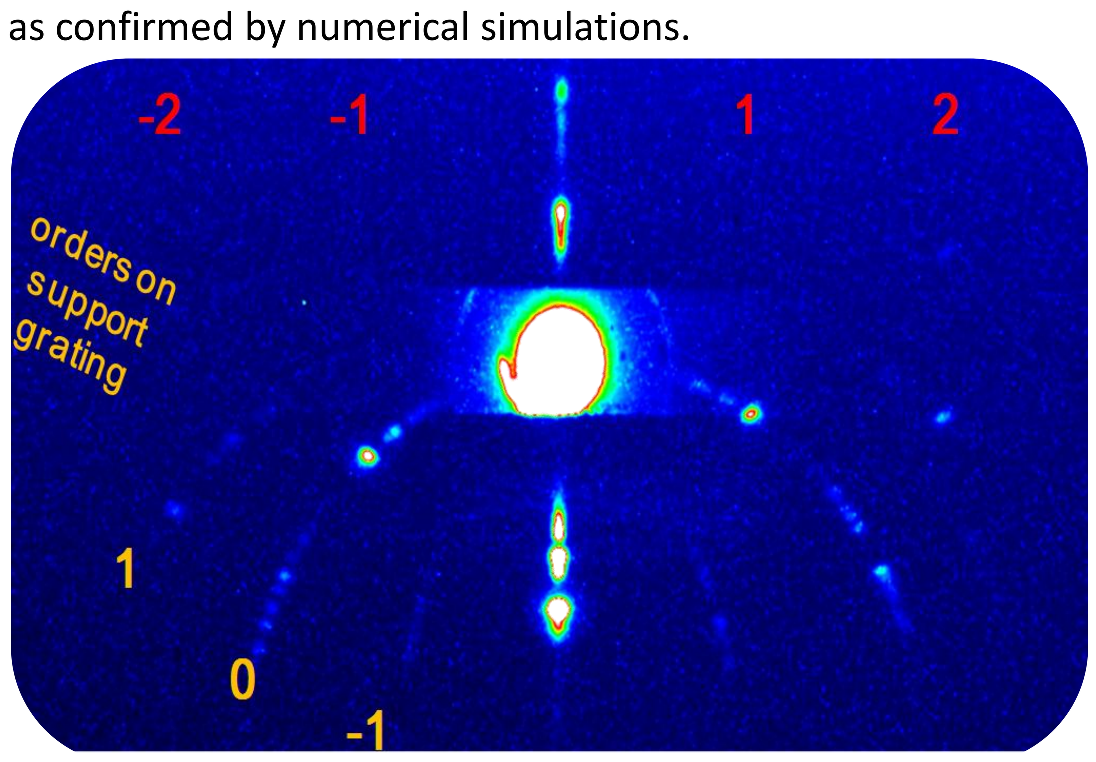
➔ Result is source size limited

Sample : Si on Si–Nitride -Membrane Grating at approx. 5° GI

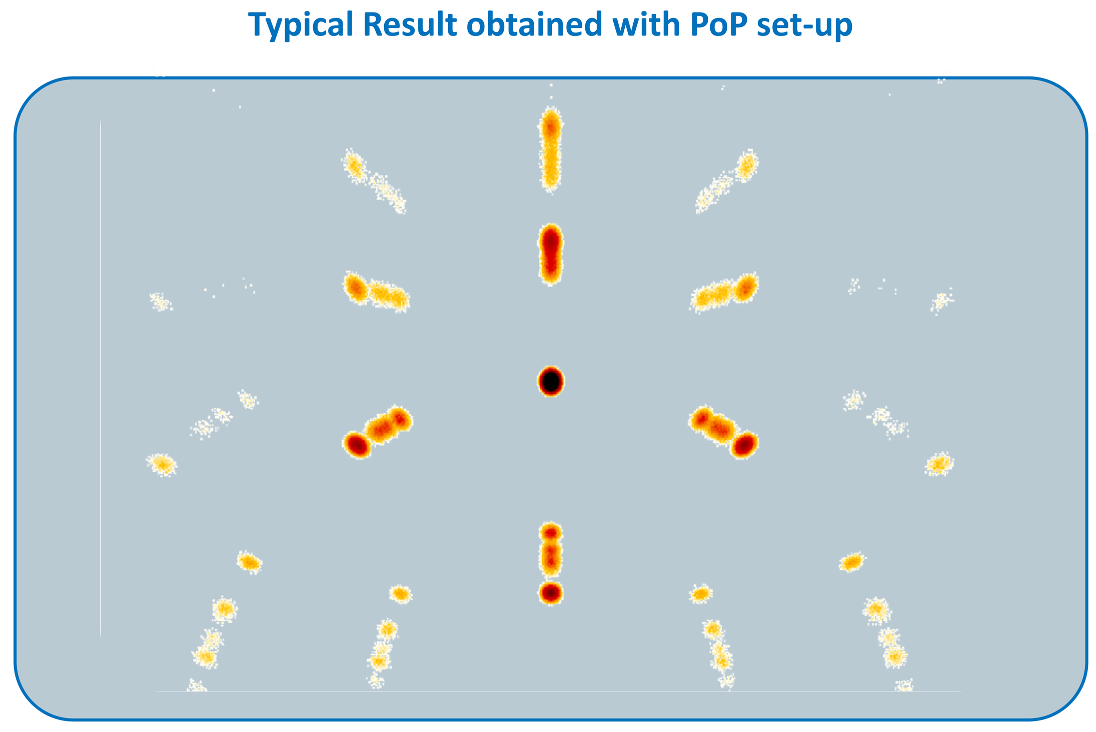
Back illuminated CCD

Results with PoP set-up

Results were obtained on 50 nm period grating on Silicon. Influence of sample spectrum and geometry is understood as confirmed by numerical simulations.



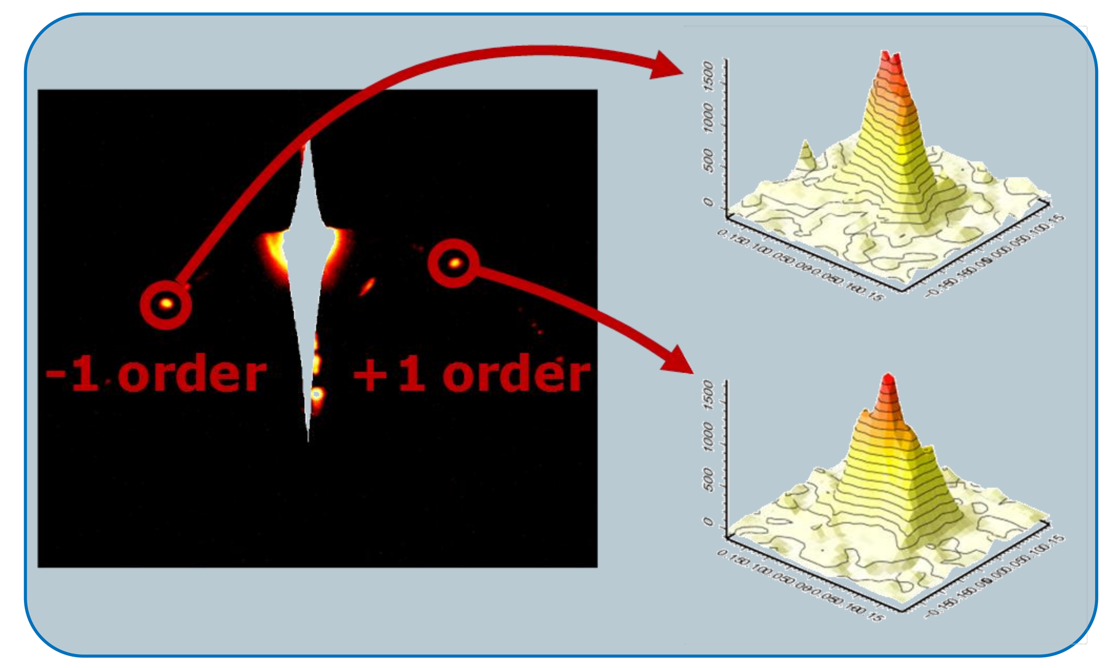
Typical Result obtained with PoP set-up



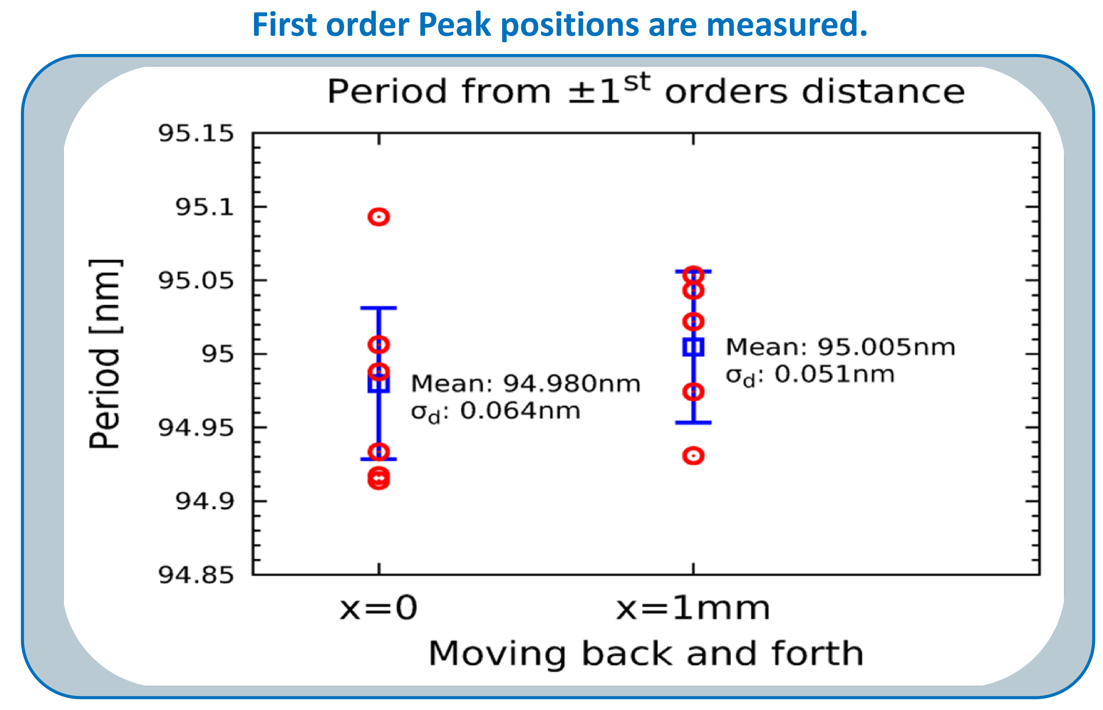
Simulation of expected result is in agreement

Preliminary Evaluation

First step of evaluation is performed on the results using first order peaks at a given wavelength (known from NIST). .



First order Peak positions are measured.



First test on reproducibility of evaluation.

13 measurements at two spots on sample (1mm lateral distance) have been performed. The period has been calculated from distance of 1st diffraction orders

- **RMS of period of 95nm is ~0.06nm**
- **Relative deviation is < 0.2% Peak-Valley**

Accuracy determined by distance spot to CCD (in proof of principle setup only ± 1mm: ==> ± 5 % mm. Can be calibrated to better 0.1 %.

Outlook

Proof of Principle results justify next steps.
Market demand ?
Benchmark to other techniques ?
Defining and Reaching target Specs.
➔Prototype
➔ Product roadmap has been studied. Extendibility is given:

Av. solutions with	λ= 13.5nm➔	5nm ➔	4nm ➔	3nm ➔	2nm
To follow roadmap of	80nm➔	30nm ➔	24nm ➔	18nm ➔	12nm

Conclusions

Status:	Promising results in PoP with < 1000 pulses (spot time < 20 s @ 50 Hz)	
Upgrade / Improvement	**Steps**	**Spot Time**
Smaller Footprint	Compromise AoI	⇑ 5x
	100 * 10 µm (50*5) slit	⇑ 10x (40 x)
Monochromaticity	Spectral Filtering	⇑ 5x
Source Optimization	Line Yield	⇓ 5 x
	Rep-Rate	⇓ 2 - 4 x
	Distance Source => sample	⇓ 10 x
	Source Collimation	
Stray Light and Noise	Shielding, Collimation, Filter placement	⇓ 2 x
Tool Target	Small spot; optimized resolution and sensitivity in n	< 2 minutes

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GI-WA-XUV-S

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